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The use of unbaited surveillance cameras to detect the presence of reptiles at three sites in Victoria

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Abstract
Remote surveillance cameras are now widely used during surveys of vertebrate fauna. Whilst camera trapping is now a standard method during mammal surveys, this technique is relatively new to reptile field studies. During surveys at three sites in southern and western Victoria, unbaited cameras were used to detect the presence of reptiles. Cameras were set at likely basking sites or near habitat often used by reptiles. Because most sites were rocky, a special camera mount was developed. Six species, comprising five skinks and one elapid snake were detected by cameras. Unbaited camera trapping at key reptile habitat sites provides an additional nonintrusive fauna survey technique. (*The Victorian Naturalist* **138** (4), 2021, 100–106)

Keywords: remote surveillance cameras, rocky sites, reptiles, camera mount

Introduction

Remote surveillance cameras are now a standard survey method for determining the presence of vertebrate fauna (Meek and Fleming 2014; Meek *et al.* 2015a; Meek *et al.* 2015b). Over the last decade, camera trapping has been used extensively to determine the presence of terrestrial and arboreal mammals (Nelson *et al.* 2009; De Bondi *et al.* 2010; Drury 2014; McLean *et al.* 2015; Bowler *et al.* 2017; Bryant *et al.* 2018; Burns *et al.* 2018; Claridge *et al.* 2019; Eyre *et al.* 2020); however, compared to mammal surveys, the use of cameras to detect reptiles has been less extensive (McGrath *et al.* 2012; Welbourne 2013; Department of Environment, Land, Wildlife and Planning (DELWP) 2015; Banks *et al.* 2017; Moore *et al.* 2020). During surveys of vertebrate fauna at two sites on the northern outskirts of Melbourne and one site in western Victoria, remote surveillance cameras without bait stations were used to determine the presence of reptiles. This paper presents the first publication using unbaited surveillance cameras specifically to detect reptiles, using a specially-designed camera mount and without the use of any additional aids that may have altered animal behaviour.

The Growling Frog Golf Course (GFGC) is located in Yan Yean (37° 56' S, 145° 07' E), approximately 33 km north-north-east of the Melbourne CBD. The golf course was developed under strict conservation guidelines that included the retention of dry-stone fences. The GFGC is managed by the City of Whittlesea and surveys of vertebrate fauna have been conducted at the property annually since 2007 (Homan 2011, 2012, 2015, unpubl. data).

The Northern Landfill Site is a major waste disposal facility in Cooper Street, Epping, (37° 63'S, 144° 96'E), approximately 18 km north of the Melbourne CBD. The facility is situated on the eastern side of Merri Creek and key conservation areas exist between the landfill area and the stream. The site is managed by the City of Whittlesea and is known as Northern Landfill Merri Creek (NLMC). Surveys of vertebrate fauna, including monitoring of a population of Growling Grass Frog *Litoria raniformis*, have been conducted annually in the area since 2009 (Homan unpubl. data).

Rhynie Pastoral Company is a sheep grazing and cropping enterprise situated in the Willaura/Maroona district in western Victoria (37° 43' S, 142° 82' E), approximately 200 km west of the Melbourne CBD. The property contains numerous conservation zones including one area of 55 ha, known as Shepherd's Hut Sanctuary, which is surrounded by a fox- and cat-proof fence. Surveys of vertebrate fauna have been conducted in the sanctuary and other conservation sections of the property since August 2017 (Homan unpubl. data).

Methods

When investigators use surveillance cameras, cameras are either strapped to a tree or a camera stake; however, in rocky, treeless sites these options are usually unavailable. The survey sites at GFGC and NLMC were rocky and therefore a special camera mount was developed to suit the conditions (Figs 1 and 2). The mount consisted of a wooden base, 250 mm × 90 mm, with a hinged vertical section, 150 mm × 90 mm, to which the surveillance camera is attached. Adjustable legs made of heavy gauge wire are attached by bolts with wing nuts to each side of the vertical section. When tightened, the adjustable legs prevent the mount from falling over sideways. Once fully assembled the mount, with camera attached, can be positioned on rocky surfaces or large fallen logs to capture images of vertebrate fauna, including reptiles. The mount can be dismantled to allow for easy transportation (Fig. 3).

Cameras used at all three study sites were Scoutguard models SG-990V and KG-680V and Faunatech Snaps. All cameras were set without bait stations and with normal sensitivity. Drift fences and other aids to direct taxa towards cameras were not used at the three study sites. Cameras at GFGC were set beside dry-stone fences and were pointing in a southerly direction to eliminate sun glare.

Cameras were not set at regular intervals, but instead were set beside sections of the fences (minimum of 5 m apart) with many large rocks and a flat rocky substrate that was considered to be a potential basking site for reptiles.

Fig. 1. Rock camera mount, front view.

Fig. 2. Rock camera mount, rear view.

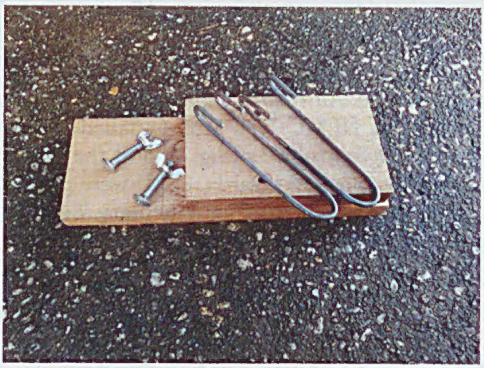

Fig. 3. Rock camera mount dismantled.

Cameras at NLMC were set on rock ledges near rock crevices in a rocky escarpment above Merri Creek (Fig. 4). Crevices and rock ledges that received late morning sun were targeted. Because of a lack of suitable sites in the rocky escarpment, several cameras were affected by sun glare. Cameras at Shepherd's Hut Sanctuary were set facing south, on or beside large logs and large fallen tree trunks.

At NLMC unbaited cameras were used in late December 2016, 2017, 2018 and 2019, completing 41 camera nights/days. During the December 2016 study, cameras were set to take 20-second videos every five seconds over a 24 hour period, but in all subsequent studies, at all three sites, cameras were set to take two still images every five seconds over 24 hours. Unbaited cameras were used at GFGC in early March 2017 and late February 2018, 2019 and 2020, completing 108 camera nights/days. Unbaited cameras were used at Shepherd's Hut Sanctuary on one occasion only, from 12 October 2017 to 26 October 2017, completing 140 camera nights/days.

Results

Six species of reptiles were recorded, comprising five skinks and one elapid snake (Table 1). Numerous images of Cunningham's Skinks *Egernia cunninghami,* both adults (n = 58) and juveniles (n = 13), and adult Common Blue-tongued Lizards *Tiliqua scincoides* (n = 14) were captured beside dry-stone fences at GFGC (Fig. 5). Smaller numbers of the Eastern Large Striped Skink *Ctenotus spaldingi* (n = 3) and the Garden Skink *Lampropholis guichenoti* (n = 1) were photographed at this site. Cunningham's Skink was photographed during all surveys at NLMC (n = 16) (Fig. 6). The Lowland Copperhead *Austrelaps superbus* was recorded once at NLMC. The Stumpy-tailed Lizard *Tiliqua rugosa* (n = 1) (Fig. 7) and the Common Blue-tongued Lizard (n = 8) were photographed at Shepherd's Hut Sanctuary. Because each study was a basic presence/absence survey, the numbers of false triggers, caused by waving grass and moving shadows, were not recorded. If a reptile of consistent size was photographed at the same location multiple times over several days, then it was assumed to be the same individual, unless some distinguishing feature indicated otherwise.

Fig. 4. Rock camera mount on rock ledge, Northern Landfill Merri Creek, Epping.

Fig. 5. Common Blue-tongued Lizard and Cunningham's Skink, Growling Frog Golf Course, Yan Yean.

Fig. 6. Cunningham's Skink, Northern Landfill Merri Creek, Epping.

Table 1. List of reptile species and estimated number detected by unbaited surveillance cameras. **ENI** = estimated number of individuals. Taxonomy and nomenclature follow Robertson and Coventry (2019).

Common Name	Scientific Name	Date	ENI	Habitat structure and location
Eastern Large Striped Skink	*Ctenotus spaldingi*	8 March 2017	1	Beside dry-stone fence, Yan Yean
		25 December 2020	1	Beside dry-stone fence, Yan Yean
Cunningham's Skink	*Egernia cunninghami*	23 December 2016	3	Rocky escarpment, Epping
		7–10 March 2017	6	Beside dry-stone fence, Yan Yean
		20 December 2017	1	Rocky escarpment, Epping
		19 December 2018	2	Rocky escarpment, Epping
		18 December 2019	2	Rocky escarpment, Epping
		25 February 2020	2	Beside dry-stone fence, Yan Yean
Garden Skink	*Lampropholis guichenoti*	25 February 2020	1	Beside dry-stone fence, Yan Yean
Stumpy-tailed Lizard	*Tiliqua rugosa*	14 October 2017	1	On fallen tree trunk, Maroona
Common Blue-tongued Lizard	*Tiliqua scincoides*	7 March 2017	1	Beside dry-stone fence, Yan Yean
		9 March 2017	1	Beside dry-stone fence, Yan Yean
		14 October 2017	1	On fallen tree trunk, Maroona
		15 October 2017	1	Under fallen tree trunk, Maroona
		20 October 2017	1	In grass beside fallen tree trunk, Maroona
		24–26 February 2020	4	Beside dry-stone fence, Yan Yean
Lowland Copperhead	*Austrelaps superbus*	22 December 2016	1	Rocky escarpment, Epping

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Fig. 7. Stumpy-tailed Lizard, Shepherd's Hut Sanctuary, Maroona.

Discussion

Survey techniques to determine the presence/absence of vertebrate fauna have changed dramatically over the past decade. Where previously live-trapping was carried out as the preferred survey method, a number of non-intrusive research instruments such as listening devices, bat detectors and remote surveillance cameras have now become standard survey equipment. Whilst camera trapping for mammals is now well-established, the use of cameras for reptile surveys is a relatively recent development (Welbourne 2014; Welbourne *et al.* 2017).

Welbourne (2013) introduced the Camera Overhead Augmented Temperature (COAT) protocol. This technique involves setting cameras vertically above small gaps, with enhanced substrates, along drift fences, so that any reptile that passes through the gap is photographed. A number of researchers have compared this method with more traditional reptile survey techniques, such as pitfall trapping and artificial habitat (Richardson *et al.* 2018; Dundas *et al.* 2019; Welbourne *et al.* 2020), whilst others have investigated survey designs, cost effectiveness, results and adjustments to camera settings and associated equipment (Welbourne *et al.* 2015; Adams *et al.* 2017; Molyneux *et al.* 2017; Welbourne *et al.* 2019). Other investigators have used this protocol to determine the presence of reptiles in targeted surveys (DELWP 2015; Banks *et al.* 2017; Urlus *et al.* 2018). McGrath *et al.* (2012) used camera trapping to determine the presence of the cryptic Grassland Earless Dragon *Tympanocryptis pinguicolla* on the Monaro Tablelands of New South Wales. During that study four cameras were set on stakes and focused on artificial burrows, without bait or drift fence, capturing a number of images of the target species. However, two cameras installed on wooden fence posts, without bait, drift fence or artificial burrows, failed to detect any reptile species.

The main purpose of studies at the NLMC site was to monitor a population of Growling Grass Frogs *Litoria raniformis*, and so the bulk of survey effort was devoted to this cause. Methods to determine the presence of other vertebrate fauna at the site therefore needed to be less time-consuming, but effective. Surveillance cameras were chosen for these reasons. The great benefit of camera trapping is that once cameras are set, no further survey effort is required until they are retrieved. When cameras were used at NLMC for the first time in December 2016, only one suitable site was located. Nevertheless, the camera set at this site captured videos of several Cunningham's Skinks and one Lowland Copperhead. In subsequent surveys at NLMC, several other suitable sites were found, resulting in additional records of Cunningham's Skinks within the rocky escarpment.

One of the purposes of the surveys at GFGC was to determine which vertebrate species were using the dry-stone fences as habitat. During annual surveys between April 2007 and March 2010, funnel trapping was used beside the extensive dry-stone fence on the western side of the property in an attempt to determine the presence of reptiles (326 trap-nights/days). This method produced records of two species only: the Eastern Large Striped Skink and Lowland Copperhead. Previous surveys at this site in October 1988 recorded Cunningham's Skink (Beardsell 1997); however, funnel trapping between 2007 and 2010 failed to capture any individuals of this species.

When Cunningham's Skinks emerge from their crevice refuge to bask, they are especially wary and are quick to retreat to safety at the first sign of danger (Stow 2004). The species also leaves distinctive scats at latrine sites (Robertson and Coventry 2019). However, at GFGC checking for scats and searching possible shelter sites with torches amongst large rocks failed to detect any Cunningham's Skinks. Whilst one individual was seen by chance on the eastern

fence in September 2014, scanning the western fence with binoculars from a distance over several years failed to detect the species. Because of significant damage to funnel traps by House Mice *Mus musculus*, funnel trapping close to stone fences was abandoned following the 2010 survey. With the development in 2016 of the rock camera mount (mentioned above), surveillance cameras were used beside the western fence for the first time in March 2017, capturing numerous images of Cunningham's Skinks, as well as several images of Common Bluetongued Lizards and one image of an Eastern Large Striped Skink.

Whilst many farmers often observe numerous species of vertebrate fauna, these records are rarely published or lodged with databases such as the Victorian Biodiversity Atlas (VBA) (P Homan pers. obs., 1966–2020). Indeed, when intensive surveys began in Shepherd's Hut Sanctuary in August 2017, the VBA showed only one reptile record for the local district, that of a Striped Legless Lizard *Delma impar* from 1990. The landowners at Rhynie Pastoral Company and neighbouring farmers had seen numerous species over many years including the Common Blue-tongued Lizard, Sand Goanna *Varanus gouldii*, Tiger Snake *Notechis scutatus*, Eastern Brown Snake *Pseudonaja textilis* and Eastern Bearded Dragon *Pogona barbata*. (J Tucker pers. comm., 10 August 2017). Shepherd's Hut Sanctuary contained many large fallen tree trunks, ideal basking sites for large reptiles such as Bearded Dragons (Melville and Wilson 2019). Unbaited cameras were set in the sanctuary in October 2017, to detect the presence of large reptiles including Bearded Dragons. Whilst this species was not detected, several Common Blue-tongued Lizards and one Stumpy-tailed Lizard were recorded. These were the first confirmed available records for these common reptiles for the Willaura/Maroona district. The other large, diurnal reptiles known to have occurred at the site that was to become the Shepherd's Hut Sanctuary were the Sand Goanna and Eastern Brown Snake (J Tucker *pers. comm.*, 10 August 2017); however, these species were not detected by cameras.

Under the Australian code for the care and use of animals for scientific purposes, 8th Ed 2013, investigators involved in field studies of fauna are expected to use a range of survey methods that are less intrusive and reduce the unnecessary use of animals. Whilst the COAT protocol is now a proven ethical reptile survey technique (Welbourne *et al.* 2015; Urlus *et al.* 2018), camera trapping without drift fence or bait or other aids that alter the behaviour of wild animals is an additional non-intrusive technique that should be considered by researchers conducting field studies of reptiles. Many reptile surveys occur in rocky areas and there are often opportunities to use unbaited surveillance cameras. Gaps between large rocks, boulders and large fallen logs should be considered as potential sites to set unbaited cameras to detect reptiles. In areas where dry-stone fences occur, unbaited camera trapping using a mount like that described in this paper would improve the chances of detecting reptiles that occupy fences.

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Little Lorikeet *Glossopsitta pusilla* nest hollow preparation and interspecific aggression in Melbourne, Victoria

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Abstract
Observations are presented of aggression between a pair of Little Lorikeets *Glossopsitta pusilla* and an Eastern Rosella *Platycercus eximius* at a nest hollow, and nesting activity by the Lorikeets in inner eastern Melbourne, Victoria. Aggression between these two species does not appear to have been previously reported, while the timing of the nesting activity (autumn) is considered unseasonable for Little Lorikeets. (*The Victorian Naturalist* 138 (4), 2021, 107–109)

Keywords: nest hollow, competition, interspecific aggression, Little Lorikeet, breeding

Introduction

In a review of the ecology of the Little Lorikeet *Glossopsitta pusilla*, Higgins (1999) suggested the breeding biology of the species was 'not well known, with no major studies' and that only 19 records were in BirdLife Australia's Nest Record Scheme to December 1995. Subsequent studies and reviews by Courtney and Debus (2006) and Horton and Black (2006) have added to the knowledge of the breeding biology of the species. The Little Lorikeet is considered to have declined in many parts of its range; for example, the species is listed as Endangered under the South Australian *National Parks and Wildlife Act 1972*, as Vulnerable under the New South Wales *Biodiversity Conservation Act 2016*, and is part of the Threatened Victorian Temperate Woodland Bird Community under the Victorian *Flora and Fauna Guarantee Act 1988*. In Melbourne, the species is considered uncommon with few breeding records (Emison *et al.* 1987; Barrett *et al.* 2003; Loyn and Menkhorst 2011). Here, I describe unseasonable nesting activity and associated interspecific aggression for this species in the inner suburbs of Melbourne.

Observations

A pair of Little Lorikeets was observed in a River Red Gum *Eucalyptus camaldulensis* at Kew Billabong, Willsmere Park, adjoining the Yarra River, Kew East, Victoria (37°47' S, 145°03' E) on 11 May 2002, at approximately 12:00. The observer's attention was drawn to the loud vocal exchange between the pair of Lorikeets and an Eastern Rosella *Platycercus eximius*, on a nearby branch, approximately 1 m away from the Lorikeets. After much vocalisation lasting approximately two minutes, in which the Lorikeets and Rosella vied for position amongst the branches (mostly within a few metres of the initial observation), the Rosella eventually flew off.

The two Lorikeets proceeded to fly alternately to a small hollow, midway along a horizontal limb of the River Red Gum, ~10 m above the ground. Over a period of 30 to 60 seconds, each bird would place its head down the hollow for about 5 seconds, then stand up before re-inserting its head in the hollow. The birds would then change over (the other perched approximately 0.5 m away). This occurred for approximately ten minutes. Whether these birds were simply investigating the suitability of the hollow, feeding young, excavating the hollow or biting off living bark encroaching on the entrance-hole (see Courtney and Debus 2006), could not be positively determined, but the routine nature of the activity and length of time would suggest the latter. Boyd (1987) and Morcombe (2000) note that hollows are cleaned and scratched out by both sexes, but both birds spend considerable time in the hollow before any cleaning is attempted. Multiple visits to the site since the initial nesting activity failed to detect the Lorikeets.

Discussion

These observations were considered to be interspecific aggression for a nest hollow. Many Australian parrots compete directly for hollows (Gibbons and Lindenmayer 2001), and related aggression is commonly displayed, particularly amongst conspecifics (Krebs 1998). Dominant species typically prevail when competing for the same hollow (Newton 1994; Courtney and Debus 2006), although few studies have looked at competition for hollows by parrots in Australian cities (Davis 2014).

Higgins (1999) stated that Little Lorikeets are 'aggressive when breeding and conflict often occurs over nesting hollows', but the sources from which this is drawn (i.e. Lendon 1950; Boyd 1987; O'Brien 1987) suggest this is intraspecific aggression with few further details. Eastern Rosellas have previously been reported competing for nest hollows with White-throated Treecreepers *Cormobates leucophaea* (Aston 1959), Rainbow Lorikeets *Trichoglossus moluccanus* (Davis *et al.* 2013), Australian King-Parrots *Alisterus scapularis* (Davis *et al.* 2013) and Scaly-breasted Lorikeets *Trichoglossus chlorolepidotus* (Higgins 1999); displaying aggression towards Adelaide Rosellas *Platycercus elegans* subsp. *subadelaidae*, Rainbow Lorikeets (Peneck *et al.* 1995; Davis *et al.* 2013), Australian King-Parrots (Davis *et al.* 2013) and Red-rumped Parrots *Psephotus haematonotus* (Higgins 1999); and visiting nests of Superb Parrots *Polytelis swainsonii* (Rayner *et al.* 2016), but do not display aggression as often as other parrots (Davis *et al.* 2013). Neither competition for nest hollows nor aggression with Little Lorikeets appears to have been previously reported (Higgins 1999). Interestingly, Little Lorikeets and Eastern Rosellas have previously been reported nesting in the same tree (North 1901–1914).

The typical hollow entrance diameter used by both species—2.9–3.2 cm for Little Lorikeets and 6–41 cm for Eastern Rosella (Higgins 1999)—would appear to exclude potential competition for nesting space (see also Courtney and Debus 2006). Horton and Black (2006) consider the Purple-crowned Lorikeet *Glossopsitta porphyrocephala* the most likely native competitor with Little Lorikeets for nest hollows in South Australia, with possible non-native contenders such as Common Starling *Sturnus vulgaris* and feral Honeybees *Apis mellifera*. Courtney and Debus (2006) noted rare occurrences of Musk Lorikeets *Glossopsitta concinna* and feral Honeybees usurping Little Lorikeet nests in New South Wales.

While high densities of Rainbow Lorikeets and Musk Lorikeets were recorded in Melbourne in the autumn/winter of 2002 associated with intense eucalypt flowering (Fitzsimons *et al.* 2003; White *et al.* 2005), Little Lorikeets were found to be relatively uncommon in that particular study (and in subsequent studies, e.g. van Polanen Petel and Lill 2004; Platt and Lill 2006; Stanford and Lill 2008; Fitzsimons *et al.* 2011). This makes the location and timing of this hollow excavation process a matter of interest. There is a paucity of Little Lorikeet breeding records for Victoria (e.g. only three reports of breeding by Emison *et al.* (1987), in East Gippsland and Central Victoria, and two by Barrett *et al.* (2003), north-west of Melbourne and in Central Victoria). Even in the past, when Little Lorikeets were perhaps considered to be more common in the Melbourne region (Wheelwright 1861; Loyn and Menkhorst 2011), they were not noted to breed in the region (although see Blyth 2017 for repeated use of a River Red Gum hollow in Werribee). Activities such as territorial fighting and nest building are considered inadequate evidence on which to define the breeding range of a species as it may follow environmental changes but does not always lead to breeding (Blakers *et al.* 1984; Barrett *et al.* 2003). Nonetheless, the observations described above do appear to be outside the normal breeding/nest preparation times for the Little Lorikeet in southern Australia, which is typically between August and January (e.g. Forshaw 1989; Courtney and Debus 2006), although there are records in April and July (Higgins 1999; Barrett *et al.* 2003) that could be influenced by unseasonal eucalypt flowering and nectar production. Further observations of breeding and nesting activity would assist in improving knowledge of the species' breeding biology and range (see also Courtney and Debus 2006).

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Fifty-three years ago

NOTES FROM THE DIARY OF AN INNER-CITY BIRDWATCHER

By Edna B. King

During most of May, numerous, noisy flocks of the Little Lorikeet, commonly called "greenies", were to be seen and heard, feeding on the blossoms of the *E. ficifolia* and strewing the roadway with the cream flowers. These birds appeared to be unaware of the approach of humans when feeding and continued with their screeching and acrobatics within a few feet of the watcher.

From *The Victorian Naturalist* **85**, p. 208, July 1968

Explosive breeding in the Spotted Marsh Frog *Limnodynastes tasmaniensis*

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Abstract
This article describes two episodes of explosive breeding in the Spotted Marsh Frog *Limnodynastes tasmaniensis*, triggered by heavy rainfall at sites on the northern outskirts of Melbourne. One episode resulted in approximately 260 egg masses being deposited in a small, shallow ephemeral pond; in the other, approximately 120 egg masses were deposited in a larger ephemeral pond. (*The Victorian Naturalist* **138** (4), 2021, 110–113)

Keywords: *L. tasmaniensis*, egg masses, breeding, rain, larvae

Introduction

The Spotted Marsh Frog *Limnodynastes tasmaniensis* (Limnodynastidae) is an abundant and widespread species within Victoria and a common inhabitant of basalt plains River Red Gum *Eucalyptus camaldulensis* woodland and grassland north and west of Melbourne, often in quite disturbed areas (Brereton 1991; Hero *et al.* 1991; Larwill 1995; Hamer 2011). When conditions are suitable, it is frequently encountered beneath surface stones, sometimes in small aggregations that have been demonstrated to reduce the rate of dehydration (Johnson 1969). During dry conditions, it lives in soil cracks and along the moist edge of watercourses or permanent water bodies (Brereton 1991; Brown 2011; pers. obs. 1984–1996). Around Melbourne the species is known to breed from August to January (Littlejohn 1963), although breeding is opportunistic and may occur at any time after heavy rain (Hero *et al.* 1991; Anstis 2013). Females are capable of depositing clutches at two-week intervals and metamorphs are able to reproduce at only 3.5 months of age (Horton 1982). The eggs are laid in compact, roughly circular, floating masses of foam-capped jelly (Martin *et al.* 1966).

Explosive breeding in frogs refers to synchronised breeding events of short duration (over several nights) utilising ephemeral habitat and involving dense breeding aggregations (Wells 1977). This article describes two instances of explosive breeding in *L. tasmaniensis* from basalt plains grasslands near Melbourne, triggered by a heavy fall of rain.

Methods

Approximately 20 egg masses and more than 50 larvae were examined with a hand-lens at each location. Eggs and larvae were identified using Martin (1965) and Martin *et al.* (1966). The larvae of *L. tasmaniensis* were readily distinguished from those of the Common Froglet *Crinia signifera*, which was the only other frog species present. The number of egg masses was (twice) estimated on-site and then checked by counting egg masses in photographs of the ponds. Rainfall data were obtained from the nearest weather recording station, at La Trobe University, Bundoora (Bureau of Meteorology 2020). The surface area of each pond was estimated by approximating it to a known shape (spindle and ellipse), measuring the linear dimensions of the pond and then computing the area of the shape; from this information the average density of egg masses was estimated.

Observations

On 21 March 1989, 55 mm of rain fell in the area and triggered breeding in *L. tasmaniensis*. Two breeding sites 3 km apart were visited by day on 23, 24 and 26 March. One site (Bundoora) was also visited intermittently through to the end of the year. Both sites were ephemeral ponds in formerly grazed remnant native grasslands. Both ponds had been completely

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dry since mid-October of the previous year (i.e. for about five months).

1. Bundoora (37° 41' 05" S, 145° 03' 19" E) The pond was spindle-shaped with a length of 9 m, almost 2 m wide at its widest point, a maximum depth 0.15 m and surface area of approximately 12 m^2. On the initial visit it contained approximately 260 egg masses with an average density of egg masses 22/m^2. A second count of egg masses on 26 March (Fig. 1) was in agreement with the initial count, indicating that no further breeding activity had occurred. Because of the pond's relatively small size, many egg masses were contiguous. There was some emergent vegetation in the pond, consisting mainly of low grasses and small stands of Upright Water-Milfoil *Myriophyllum crispatum*. At least 50 male *L. tasmaniensis* and about 10 *C. signifera* were calling from water at the margins of the pond during the initial visit. Immediately surrounding the pond were low grasses (< 0.3 m; mainly *Poa* sp.). *Limnodynastes tasmaniensis* has been recorded breeding in previous years at this pond in spring in response to substantial rainfall (pers. obs. 1984–88), but in this instance the number of egg masses was double those previously recorded.
2. Mill Park (37°39'47" S, 145°04'31" E) The pond was located in a disturbed grassland area, littered with refuse, in an elliptical depression 7 m × 4 m (at its widest points), with a maximum depth of about 0.4 m. Rusting iron water tanks, scrap metal, broken terracotta pipes, lumps of concrete, etc. provided concealment for both frogs and egg masses. Approximately 120 egg masses were located with an average density of about 5.5/m^2. A second count on 26 March (Fig. 2) indicated there were no new egg masses. Approximately 20 male *L. tasmaniensis* were calling in and around the margins of the pond when first visited. Egg masses were located in water ranging in depth from 0.05 m to 0.4 m, and about two-thirds of the egg masses were abutting other masses.

The egg masses at both sites were 60–80 mm in diameter and, although few were measured, none appeared to lie outside this range. This is consistent with previous records of *L. tasmaniensis* egg masses from Victoria (Martin *et al.* 1966; Hero *et al.* 1991). The only other lo-

Fig. 1. Small ephemeral pond in Bundoora with approximately 260 Spotted Marsh Frog *Limnodynastes tasmaniensis* egg masses recorded on 26 March 1989.

Fig. 2. Large ephemeral pond in Mill Park with approximately 120 Spotted Marsh Frog *Limnodynastes tasmaniensis* egg masses recorded on 26 March 1989.

cal species that lays foamy egg masses is the Eastern Banjo Frog *Limnodynastes dumerilii dumerilii*, whose egg masses are considerably larger (120–180 mm diameter; Hero *et al.* 1991). This species was not present at these sites.

There was no rain for at least six days after the initial heavy fall and the lack of fresh egg masses at either site indicated that breeding had ceased. Egg masses that had been laid earliest were identified by their flattened and partly dried appearance. There appeared to be some disturbance of egg masses deposited on the first night, caused by breeding activity on the second and third nights. On subsequent visits to both ponds, larvae were observed in shallow water (< 0.05 m) close to the margins, mostly on the substrate. With significant follow-up rain in early April, June, and July (daily maximum rainfall 59, 33 and 26 mm respectively), both ponds contained some water until late September. Metamorphosing *L. tasmaniensis* larvae were first recorded from the Bundoora pond in early September. Small numbers of males were vocal (by day) when sites received follow-up rain in June and July, but no additional breeding activity was recorded until late September when 13 egg masses were located at the Bundoora pond.

Discussion

Rainfall is the primary stimulus to breed for most species of anurans (Duellman and Trueb 1986). Both breeding events were triggered by one fall of rain of 55 mm, the highest daily total for March recorded in the area since records began (1979–2020). Local populations of *L. tasmaniensis* more commonly breed in spring (pers. obs. 1984–88; BoM 2020), but are obviously capable of breeding in autumn when conditions are favourable. In the Melbourne area, Martin (1965) noted that metamorphosis in *L. tasmaniensis* may occur after three and a half months, with metamorphs recorded from September to January and March to May. However, he added that larvae hatching in late summer or autumn may overwinter and not metamorphose until the following spring. That was the case here, with the larvae overwintering and metamorphosing in spring, after a larval lifespan of five and a half months.

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Our Mallee — from degraded to resilient: restoration through fauna reintroduction

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Abstract
The mammalian fauna of the Victorian Mallee region is the most depauperate in the state, with the greatest species loss. In recent years, land management has improved and some habitats (whilst still degraded) are slowly recovering aspects of function and quality, with notable progress to date. Is it time to consider reintroductions of species which are now extinct in Victoria, but can still be found elsewhere, particularly species that help restore ecosystem function? Focusing on Hattah-Kulkyne National Park, this project investigated the possibilities and opportunities involved and concluded that reintroductions are both feasible and desirable. A staged reintroduction program is outlined. Restoration of (part of) the original mammal fauna most likely will improve overall ecosystem resilience and thus biosequestration of carbon. Victoria can exploit the knowledge gained in such reintroductions in other states and territories and recover from its current malaise in faunal restoration. (*The Victorian Naturalist* **138** (4), 2021, 113–120)

Introduction
The semi-arid north-west of Victoria (the Mallee region, named after the most widespread vegetation community) was selected and settled by Europeans relatively late in the history of the state. Only since the First World War has settlement been intense, clearing extensive (Kenyon 1982; Mansergh *et al.* 2006; Burch 2017) and remaining crown land licensed or leased for grazing/logging. Nevertheless, the native fauna was already disrupted by the introduction and spread of new predators, notably European Red Fox *Vulpes vulpes* and Feral Cat *Felis catus* (Menkhorst 1995), and the effective loss of the former apex predator Dingo *Canis lupus dingo* and reduction/cessation of hunting by local indigenous groups (Burch 2017). As a result, the fauna of the Mallee is the most disrupted in the

state and has the highest level of mammalian extinctions. Ecological function across all trophic levels has been affected by the absence of these fauna. Indeed, with the exception of Short-beaked Echidna *Tachyglossus aculeatus,* nearly *all* the medium-sized dryland mammal fauna (i.e. between the size of Ningauis *Ningauis* spp. and kangaroos *Macropus* spp.) are regionally extinct. Excluding bats[1], at least half of the former terrestrial mammal fauna is now regionally extinct (18 species from a total of 32; plus a further five species whose former presence is uncertain) (Robertson *et al.* 1989; Bennett *et al.* 2006).

This regional list of extinctions includes some that have become extinct globally (e.g. Pig-footed Bandicoots *Chaeropus ecaudatus* and the eastern Australian subspecies of Numbat *Myrmecobius fasciatus rufus*). However, regionally extinct species can still be found elsewhere in Australia, although many have threatened status. Can and should we restore these extant species to the Mallee landscape and to Victoria?

When created (1980–1990s), the current semi-arid zone park system (now over 1 000 000 ha) inherited the most degraded land-systems of any large-scale natural area in Victoria. The total biomass (bio-sequestered carbon) and its diversity had been massively depleted. Over the subsequent three decades of management, progress has been made on the massive soil erosion issue and the recent re-watering of the Kulkyne has led to demonstrable improvement in riparian environments (Burch 2017). The lack of vegetation regeneration due to overabundance of European Rabbits *Oryctolagus cuniculus* and kangaroos (*Macropus* spp.) continues to keep the majority of the park area in a degraded and unbalanced state, although there have been notable achievements in habitat restoration in parts of the park, following localised control over these herbivores (Walters 1986; Sluiter *et al.* 1997; Murdoch 2006; Cheal 2009a; Cheal *et al.* 2013). Such control over relatively small areas of the park system consumes half the current and on-going park budget (P Pegler, Parks Victoria, pers. comm.).

Utilising funds made available by a private philanthropic organisation (the Burch Trust), *Parks Victoria* commissioned a study to test the ecological desirability and feasibility of reintroducing regionally extinct species to north-western Victoria, focusing on Hattah-Kulkyne National Park as a potential re-introduction site. The report from this study has been completed and submitted to Parks Victoria for their consideration (Mansergh *et al.* 2017). Here we provide a short summary of the salient outcomes.

Report Outcome

An expansive list of reintroduction possibilities was initially devised and then assessed for feasibility and availability of source animals. Based on a consideration of local habitat suitability and reintroduction programs elsewhere in Australia, feasibility criteria were established as:

1. Species known or highly likely to have occurred previously in Hattah-Kulkyne National Park.
2. Ecological niche of species and importance of their roles in ecosystems (eco-engineers).
3. Habitat availability[2] at present or in the foreseeable future—with or without management action.
4. Availability of suitable source populations.
5. Adequacy of knowledge and access to available expertise.
6. Significance of species to Traditional Owner knowledge and culture.[3]
7. Minimisation of the need for semi-captive breeding facilities either on or off site.
8. 'Bling' factor (extent to which the public is familiar with the species and likely to judge them worthy of efforts).

Thirteen species (12 mammals and one bird) were in the final 'suitability' list. Other species were excluded for a variety of reasons; for example, animals may not be available for translocation from other states or there was neither practical experience of the species in the semi-wild nor in translocations. Table 1 lists the species considered. Importantly, this suite of species was selected for representatives across the trophic levels and a variety of eco-engineering capacities currently absent across the landscape (carnivores, insectivores, granivores, fungivores, grazers, soil movers and nutrient/fungi dispersers, e.g. see Eldridge and James 2009).

As the project was focused on Hattah-Kulkyne National Park, the two meso-predators in this list of candidates (i.e. Chuditch *Dasyurus*

geoffroii and Wambenger *Phascogale calura*) were excluded on the basis of requiring very large home ranges and thus a very large area for relatively few individuals. The Dingo was likewise excluded but, as a remnant population still occurs in the Big Desert, it remains a possibility to envisage subsequent re-introductions to restore an operative apex predator to the landscape. Despite increasing scientific evidence of the value of apex predators (e.g. Wallach *et al.* 2011), the Dingo remains a major politically engaged issue. Notwithstanding, the role of predators is of critical importance within any 'exclosure' as there must be a mechanism to control likely overabundance of grazers and consequent vegetation/soil degradation (e.g. see Yugovic 2019).

The seven suitable species are discussed briefly below. For more expansive consideration of each species, see Mansergh *et al.* (2017). It is noteworthy that all these species have had ranges that extended well into the arid zone and should be able to survive climatic changes indicated for the semi-arid parks in north-western Victoria (see <www.climatechange.vic.gov.au/__data/assets/pdf_file/0023/60746/Loddon-Mallee.pdf>). Indeed, their presence as active ecological agents would assist vegetation and soil recovery now and ecosystem resilience into a climatically changed future and enhance biosequestration of carbon (Newell 2009).

Wopilkara *Leporillus conditor* – This large rodent has already been successfully (re) introduced in a number of locations in South Australia (Moseby and Bice 2004). Its catholic food requirements and tolerance of disturbed habitats, along with its large stick nests (enabling interpretation for the public and a means of assessing population size) gave this species its priority for reintroduction to Hattah-Kulkyne.

Woylie *Bettongia penicillata* – The rabbit-sized Woylie is one of the formerly common and widespread small macropods now regionally eliminated. It has been successfully reintroduced to a number of sites in New South Wales (NSW), South Australia (SA) and Western Australia (WA) and source animals are readily available; e.g. Smith *et al.* (2020). Its diet of fungi and bulbs means that a single animal (1.3 kg) may move over two tonnes of soil each year assisting propagule dispersal and aeration. The National Recovery Plan (Yeatman and Groom 2012) for the Woylie indicates that reestablishment in north-western Victoria is compatible with national recovery (Action 6). There are source populations that are available and the importance of genetic robustness of the founder populations is recognised (Actions 3, 4 and 6).

Australian Bustard *Ardeotis australis* — This spectacular, diurnal, ground-dwelling bird is now extremely rare in Victoria. Nevertheless, animals are readily available from a captive breeding project at Serendip (near Geelong), including staff experienced in handling and breeding these birds. They require relatively large areas of grassland and open woodland, as are now widespread in Hattah-Kulkyne.

Marl *Perameles bougainville* — Once widespread across arid Australia, this bandicoot is long-extinct in Victoria. It has been successfully reintroduced to the Arid Recovery Centre in SA.

Numbat *Myrmecobius fasciatus* — The eastern subspecies of Numbat is globally extinct, but the western subspecies has been successfully introduced, as an ecological replacement, in private reserves in NSW and SA. The Numbat is one of the few diurnal marsupials, thus offering a potentially valuable experience for park visitors.

Greater Bilby *Macrotis lagotis* — The threats to this one remaining species of Bilby are well known. Bilbies have a relatively high public profile amongst threatened Australian mammals. There are reintroduced populations in NSW, Queensland (Qld), many locations in SA and some in WA. They are also held in captivity in the Australian Capital Territory (ACT) and Northern Territory (NT). Animals are readily available and there is a considerable body of knowledge about how to manage reintroductions (Anon. 2017c; Lyons *et al.* 2018).

Boodie *Bettongia lesueur* — The Boodie was once widespread across arid Australia but in recent times has become restricted to a few islands and the adjacent mainland of WA. It has been reintroduced in SA (Moseby *et al.* 2011) and NSW (at Scotia Sanctuary, near Mildura). Boodies are a major ecosystem engineer, critical in maintenance of many plant species by providing disturbed sites for seedling establishment (Eldridge and James 2009) and probably

fungal spore dispersal. Successful reintroductions at the Arid Zone Recovery Centre have found this species could become overabundant after 17 years and adversely affect Woylie populations (Sarah Legge, pers. comm. 6 May 2016). Where introduced together, management should ensure sufficient preferred habitat for the Woylie, probably through an appropriate fire regime.

The three species discussed below are less suitable candidates for reintroduction at present, but may be considered in the future.

Kultarr *Antechinomys laniger* — This small insectivorous marsupial has suffered catastrophic declines in parts of its former range, but populations seem to have been largely unaffected in WA and the NT. Very little is known of its biology, so it is not favoured for reintroduction to Victoria at this stage.

Plains Rat *Pseudomys australis* and Bolam's Mouse *Pseudomys bolami* — These small mouse-like rodents are found in nearby arid lands in SA and NSW but almost nothing is known of their biology and the reasons for their extinction in Victoria. Therefore, they are not recommended for reintroduction to Victoria at this stage, but should be considered when 'boom' conditions lead to considerable population increases in the source localities. As *Pseudomys* species, they are almost certainly granivorous, and the boom-bust cycle suggests their role is part of a longer arid zone ecological cycle.

Table 1 lists the species considered suitable for reintroduction and prioritises them according to the seven of the eight criteria outlined above.

Experience in other states over the decades has shown that (re)introductions are only likely to succeed when critical preconditions have been met, including that the reasons for previous extinction no longer operate (or can be controlled) and the species' other various habitat requirements are met at the (re)introduction site. Furthermore, Hattah-Kulkyne National Park serves purposes other than species conservation and the precise site for (re)introductions should have only minimal adverse effect on such uses and on-going management activities. As it is strongly suspected that novel feral predators are part of the reasons why these species became regionally extinct (Christensen 1980; Low 1999; Moseby *et al.* 2011; Priddel and Wheeler, 2004), predator-free exclosures or islands are a critical component of any (re) introduction success (Anon 2001; Anon 2017a and 2017b; Mansergh *et al.* 2017). The preferred location of an exclosure in Hattah-Kulkyne was assessed on the following criteria:

- ready access, but with minimal existing track closures;
- exclusive of existing camp grounds;
- habitat types and habitat diversity enclosed;
- vegetation condition within;
- exclusive of targeted managed sites for rare and threatened flora;
- exclusive of areas likely to be flooded (from Chalka Creek);
- exclusive of utility lines; and
- species intended for (re)introduction.

On these criteria, the area bounded by the Murray Valley Highway (to the south), Stockyard Track, Chalka Creek Track and Kramen Track proved the most suitable focus for (re) introductions, including the construction and maintenance of a large exclosure. This area is referred to as 'Kramen Mallee'; see Fig. 1. For a more expansive discussion of the criteria and their prioritisation, see Mansergh *et al.* 2017).

Victorian context of faunal reintroductions and new knowledge

In the 20th century, the Victorian effort in recovering the mainland Koala population from animals originally introduced to French Island, was arguably one of the most successful species recovery programs globally (Menkhorst 1995). Over the last three decades, however, WA and SA have led in this form of species recovery (Primack and Drayton 1997; Anon 2001; Anon 2017a, b, c; Marriott 2017; Kern 2018; Lyons *et al.* 2018). More recently, NT, Qld, NSW and ACT have progressed rapidly also (Gordon and Lawrie 1980; Anon 2017b; Marriott 2017). At the national level, Victoria has been conspicuously underperforming in this area (unsuccessful attempts will not be catalogued here) and its relevant management agencies appear to be characterised by a lack of imagination. Further, as the subject species are extinct in Victoria, there appears no formal representation of the Victorian experience nor input on National Recovery programs, and thus no knowledge/ inspiration transfer, such as could be gained

Table 1. Candidate species showing ranking against decision criteria, ordered into tactical phase, and showing indicative area required. The criterion relating to Tradtional Owner significance is on purpose blank (see ferasibility criteria, p. 114 above). Tactical phases I to III are the progressive periods within which groups of species are reestablished. Generally, these progress from easier to increased difficulty.

Tactical Phase	Species (nomenclature Table 1)	Re-establishment Decision Criteria (H = High; M = medium; L = Low)								Area (Km^2)
		1	2	3	4	5	6	7	8	
I	Wopilkara *Leporillus conditor*	H	H	H	H	H		H	H-M	> 3
	Woylie *Bettongia penicillata*	M	M	H	M	H		L	H	> 5
	Marl *Perameles bougainville*	H	M	M	M	M		M	H	> 5
	Plains Rat *Pseudomys australis*	M	L	M	M	M		L	L	>3 ?
	Bolam's Mouse *Pseudomys bolami*	M	L	H	L	L		L	L	>3 ?
	Australian Bustard *Ardeotis australis*	H	M	H	H	H		H-M	H	>5
II	Boodie *Bettongia lesueur*	H	H	H	H	H		M	H	> 200
	Numbat *Myrmecobius fasciatus*	L	H	M?	H	H		H	H	>20
	Kultarr *Antechinomys laniger*	M	L	M	L	L		L	L	> 200
	Bilby *Macrotis lagotis*	H	H	M	M	M		M	H	>100
	Bridled Nail-tail Wallaby *Onychogalea fraenata*	M	H	H	M	H		M	H	>40 ?
III	Chuditch *Dasyurus geoffroii*	M	H	M	M	M		L	H-M	>5000
	Wambenger *Phascogale calura*	M	L	L	M	M		L	L-M	>1000?
IV	Release into the broader landscape.									

from the successful reintroductions to the now predator-free Dirk Hartog Island in WA. For example, reintroduction programs are hardly mentioned in *Victoria's Biodiversity* (1997), an otherwise commendable document, and scant mention is made in the recent *Protecting Victoria's Environment — Biodiversity 2037* (see <www.environment.vic.gov.au/biodiversity/biodiversity-plan>). That said, the strategy supports Traditional Owner involvement, which has—as a priority—the restoration of totems to country.

Victoria has a number of successful institutions germane to the Mallee reintroductions; notably, the Centre for Environmental Stress and Adaptation Research (CESAR) in the critical area of genetics (Weeks *et al.* 2017), and Mt Rothwell for semi-wild reintroductions (<www.mtrothwell.com.au>). Furthermore, recent biodiversity nationwide 'audits' have shown predator-proof enclosures now make a significant contribution to the conservation (extinction avoidance) of nationally threatened species (Lyons *et al.* 2018; Moseby and Bice 2004; Priddel and Wheeler 2004; Smith *et al.* 2020).

The knowledge base gained through the pioneering work in multiple reintroductions of these species in other states lessens the risk of

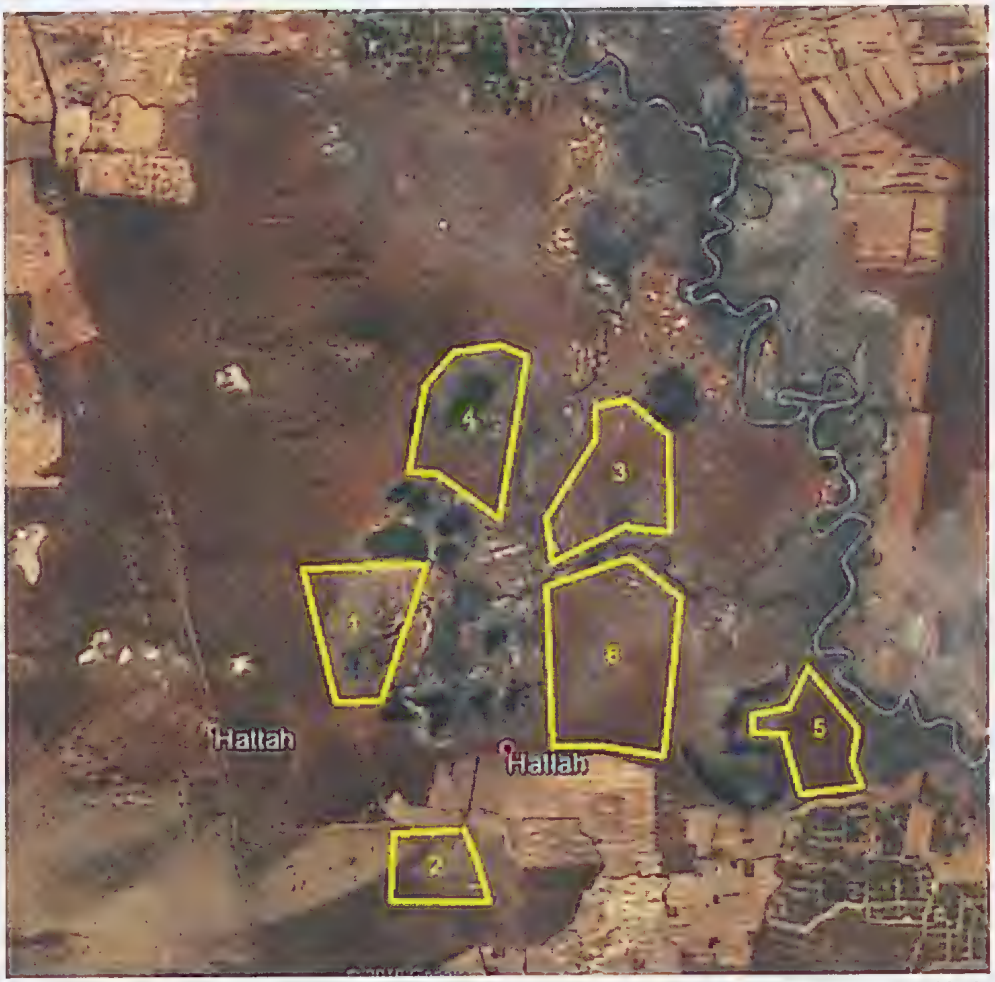

Fig. 1. Sites assessed for large exclosure and animal reintroductions: 1. Mournpall Paddock, 2. Lendrook Plain, 3. Cantala, 4. Western Mallee, 5. Messengers, 6. Kramen Mallee.

failure in Victoria. Furthermore, our increased ecological understanding of trophic cascades (Newsome and Ripple 2015), the diets of semi-arid mammals (particularly fungivory), and the role of fossorial mammals in soil health and consequent vegetation health (Eldridge and James 2009), all support our contention of the feasibility and desirability of reintroductions as a key feature of ecological restoration. An additional benefit is that another population will increase the security of many of these nationally endangered species. Victoria's poor record in these endeavours, can now gain from the work of others and possibly contribute to the national effort, by demonstrating the restorative role of multiple reintroductions in enhancing trophic level resilience.

The potential adverse effects of overgrazing (lack of predation) within the exclosure is a long-term issue (Yugovic 2015, 2019) and we do not propose reintroduction of the apex predator within such a small exclosure. However, much recent work on Dingoes is confirming their apex predator role — control of grazers and meso-predators, e.g. in the Big Desert (Nimmo *et al.* 2015) and the Mallee region generally (Sandell *et al.* 2002) nationally endangered offering evidence that Victoria can

move from continuing persecution to better understanding and enhancement in and of our large national parks. A future in which the reintroduced species are able to persist outside the initial exclosure can be readily envisaged.

Through reintroductions of mammals overseas, recent science has demonstrated the role of predators and the role of multiple grazers in restoring effective trophic layer health (Tree 2018) and, in Australia, the magnitude of native mammals in 'eco-engineering' is becoming increasing clear (Davies *et al.* 2019). What we urgently need here is demonstration (pre- and post-data) that shows intelligently chosen, multiple reintroductions can restore ecological health at the landscape scale. Although it would better protect endangered species, the Hattah-Kulkyne proposal is **not** based on single species conservation. Its inherent value would be to demonstrate that the restoration of trophic level health through multiple species reintroductions has the capacity to radically increase the health and resilience of our most degraded ecosystems. The increased value of bio-sequestration of carbon (over the one million ha of our semi-arid zone parks) would repay the economic outlay a hundredfold. The implications for our CO_2 emissions and all of semi-arid Australia are obvious.

Mansergh *et al.* (2017) provide further detailed recommendations and preliminary budgets of a staged reintroduction. The major capital expense is in erection of a predator-proof exclosure, involving approximately 50 km of perimeter fence and 30 km of internal paddock fences. Ongoing maintenance and required research are also included.

Conclusions

Reintroduction of a number of animal species formerly found in north-western Victoria, but now extinct there, is practically feasible and ecologically highly desirable. Much of the earlier associated risk with such projects can be alleviated by the science gained in the direct experience of other states. Further, securing a range of nationally endangered species will be a benefit; but a far greater benefit will be understanding how these reintroductions restore some natural resilience and increase diversity and biomass to these most degraded landscapes in Victoria. Reestablishment of some original fauna is a continuation of the vision that has driven local restorative land management since the Land Conservation Council report and recommendations more than 40 years ago (Land Conservation Council 1974, 1977). There have been notable achievements in habitat rehabilitation in Hattah-Kulkyne National Park over the last few decades (Sandell *et al.* 2002; Cheal *et al.* 2007, 2009; Cheal 2009b; Sandell 2011). This habitat and vegetation recovery has enabled consideration of further restoration of this disturbed landscape. Experimental reestablishment of native fauna is a continuation of this vision and offers the realistic possibility that the landscape can be made more resilient to foreseeable future changes. Furthermore, the capacity of landscape bio-sequestration of carbon can be demonstrated at the national scale.

As Victorians, it is now time to implement a new, but ecologically feasible and desirable, restoration program for the Mallee, based on new scientific knowledge, to enhance the capacity of the ecosystem to self-repair and increase its inherent resilience. Victoria's biodiversity and our climate deserve no less.

Notes

1. Bat taxonomy has been subject to substantial changes over the last few decades. As a result, species identity in earlier records is often uncertain. That said, no species has been identified as becoming extinct in the Victorian Mallee.
2. 'Habitat availability' includes a consideration of the reasons for original extinction in Victoria and elsewhere, plus whether these reasons for extinction no longer operate or have been substantially controlled.
3. This important criterion was specifically excluded from analysis, but was to be taken up by Parks Victoria on completion of the report in 2017; no additional information is available to date.

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Saunders Case Moth *Metura elongatus* colonies in Melbourne, Victoria

The family Psychidae, to which case (or bag) moths belong, has a world-wide distribution of approximately 1000 species. The larvae (caterpillars) are enclosed in portable, protective shelters that they make from caterpillar silk, to which they attach plant material, detritus or sand grains. They eat a wide variety of food plants. As the caterpillars grow, they go through a number of developmental stages called instars. At the end of each of these stages, they become inactive and shed their skins. Eventually they pupate, turning around inside the case so that the head points downwards, and develop into moths in their final (adult) stage. In many species, the adult female moths are wingless and never leave the case: they emit pheromones which attract the winged males. Mating occurs and, in species with wingless females, eggs are laid and hatch inside the case. The lifecycle begins anew as tiny juvenile caterpillars disperse, often with the help of the wind, on threads of silk.

My focus will be on one species of the Psychidae family, the Saunders Case Moth *Metura elongatus*.

I can still vividly recall the evening in 1994 when I first saw the black-and-orange head and thorax of a Saunders Case Moth caterpillar emerge from the top of the case I had collected and left on the kitchen bench. Recently, I have been pleased to discover that no less a person than Sir Frederick McCoy experienced a similar moment. McCoy (1817–1899) was a towering figure in nineteenth-century natural science.

McCoy's account of his initial encounter with case moth larvae is delightful. It occurred in December 1854, on the very first evening he arrived in Melbourne, having travelled from Ireland (McCoy 1885: 41).

> The extraordinary insects figured on this plate are amongst the most curious and striking of the 'common objects' in Australia, meeting the eye everywhere, from the abundance of the conspicuous protecting sacks or cases which the larvae construct and carry about with them, hanging to the trees in all directions, fixed by the uppermost anterior end and swinging loose otherwise.
>
> A young friend, walking with me in Richmond Park, the first evening I arrived in the colony, collected a number of these cases from the trees and as they were too strong and tough to be opened, and were perfectly closed, it was taken for granted they were cocoons containing pupae only, when put in his pocket; and no more was thought of the matter until they created a commotion in the drawing-room soon after by crawling actively out over the head and dress of my inquisitive friend; none of the older residents in the room having ever seen the living larvae, or suspected their existence in the well-known cases—so vigilant and timid are the caterpillars in retreating at the approach of danger.

The reference to a 'plate' in the first line refers to a drawing made by McCoy's assistant, Arthur Bartholomew, which confirms the species as the Saunders Case Moth. Richmond Park, the scene of the walk, is located in a bend of the Yarra River. Today Burnley Park and Burnley Golf Course are all that remain of the large area that was gazetted as Richmond's first public park in 1862.

McCoy's description tells us that there was an 'abundance' of case moths in Melbourne at that time. His wording and mention of the ease of collecting cases indicates that he was not observing individuals but aggregations or colonies. Saunders Case Moths still inhabit Melbourne's parks and suburban gardens, although it is likely that their numbers have declined as the city has expanded. They have adapted to urban life, feeding on exotic garden plants and attaching to man-made structures. Over the years, I have observed quite a few individuals and have had them reported to me by those who know of my interest. I can also confirm that aggregations of Saunders Case Moths are still to be found in suburban Melbourne.

The first colony I observed some years ago was found in a side-street off Brunswick Street in the inner suburb of Fitzroy. Part of a cypress tree, planted in a small backyard, was hanging over a fence. There were an estimated 70 or more individual cases visible. I collected two that were fused together, both containing healthy caterpillars, but did not continue to monitor the group (Broadberry 1999).

Another aggregation of Saunders Case Moths was pointed out to me by Barbara Burns around 2005. Its location was unexpected: the traffic islands and power poles at a busy intersection in Lower Templestowe (Fig. 1).

Fig. 1. Saunders Case Moths cases on traffic islands (top) and poles (bottom), Lower Templestowe.

Nearly all the poles at the intersection had a few Saunders Case Moths attached. A large number of cases were visible on a wooden power pole at the south-eastern corner of Foote Street and Thompsons Road (which becomes Union Road). There were clusters of 20–30 a metre or two from the ground; some of the caterpillars had climbed to the highest point and were hanging just below the power lines. A few were observed on the surrounding painted metal poles supporting traffic lights and other structures.

The food plant for this colony was Golden Guinea Flower *Hibbertia scandens*, planted on the traffic islands. Golden Guinea Flower is an adaptable plant with large yellow flowers and glossy green foliage. As a groundcover it forms a dense sprawling mat approximately 50 cm in height. Case moth caterpillars can do a lot of harm to plantings, because they feed on leaves and break off sticks to build their cases. The areas of Guinea Flower closest to the wooden pole showed considerable damage.

Although I estimated there were in the region of 150 cases in total, many were empty. This was ascertained by gently squeezing those I could reach and by the faded grey colour of the twigs attached to the cases. Cases with live caterpillars inside feel plump and the sticks are brown or green. I was in fact looking at a colony which had built up over time and had left behind a record of its history. The sturdy twig shelters are long-lasting and usually firmly attached. They can remain for years. Interestingly, the majority of empty cases were of a similar size, approximately 50–60 mm in length, which is only about half the size of the case of a fully grown caterpillar. They may have been parasitised by wasps, which can devastate a colony. I did notice several cases with dark, cylindrical pupal membranes protruding from the rear opening, which indicated that male moths had emerged.

Despite the large number of empty cases, the aggregation at the intersection was still active. A number of the caterpillars were seen to be moving, including the one in the photograph close to the traffic light button (Fig. 2). I did not place it there! A couple of tiny juveniles in their very first leaf-shelters were found on the Golden Guinea Flower at the base of the pole (Fig. 3).

Fig. 2. Saunders Case Moth crawling on a traffic light pole.

Fig. 3. Juvenile Saunders Case Moth case.

Golden Guinea Flower was growing on all the traffic island and median strips at the intersection. Upon examining these, I found a few live case moths some distance away from the main group. It seemed impossible that they had crawled there through the traffic, although the caterpillars do move remarkable distances. The reason that female case moth larvae climb so high before they pupate is to aid the dispersal of their young on threads of silk blown by the wind. It is highly likely that the newly emerged juveniles crossed the road on their silken parachutes. A couple of months later the local council refurbished all the traffic islands and median strips and replaced the Guinea Flower. Although I noticed old cases on the pole for a long time, the colony had been destroyed.

A third colony of Saunders Case Moths was brought to my attention by my daughter in early March 2019. One side of a tall cypress tree *Thuja occidentalis 'Smaragd'*, growing in the front yard of a house located on the corner of a main road in Preston, was densely populated with cases (Figs 4 and 5A). Unlike the Templestowe colony, virtually every shelter contained a live caterpillar. Many of them sported recently added green foliage. The fern-like, curved branchlets of the cypress gave the twig shelters a distinctive appearance, as if the caterpillars were wearing skirts. More than 130 cases were visible but there were probably even more (Figs 5A and 5B). The height and tightly furled shape of the cypress meant that I could examine only its lower branches. Being well aware that taking photographs and staring into a stranger's front garden would be considered odd—or even suspicious—behaviour, I kept my visits brief.

Fig 4. Site of the Preston Saunders Case Moth colony.

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75507

Figs 5A (left) and 5B (right). Saunders Case Moth cases crowded together in the Preston colony.

I checked the cypress every two weeks or so. The colony, with its abundance of cases, remained active into late July. Some caterpillars could always be found moving around the tree, the fence or the brickwork. About a third of the tree, closest to the wall of the house where the caterpillars congregated, had suffered a large amount of damage. The rest of the tree, as viewed from the front fence, was green and healthy.

A raised concrete slab formed a small porch along the front of the house. There was a gas meter, three rubbish bins and a garden tap near the tree, meaning there would have been some human activity in the area, but the cypress was never cut back even though one side looked very untidy. In mid-June, I noticed dozens of cases lying on the ground around the trunk of the tree, indicating serious interference of some kind, possibly by birds (Fig. 6). Ravens *Corvus* spp., for example, are quite able to open the tough cases and eat the caterpillars inside.

By late September 2019, there were fewer active caterpillars on the lower branches. Twenty or more stick-shelters were attached to surrounding structures. Some cases were squashed on the pavement. The colony was clearly in decline. It seemed that most of its members had dispersed elsewhere or had perished. I continued to visit the site periodically until spring 2020. A few cases could still be seen attached high on the building and one or two were still hanging from the tree, but the once thriving colony was no more.

Saunders Case Moths live on in the Preston area. I have access to two large gardens a few blocks from the aggregation I have described. Each contains 20 or more active cases including many juveniles. The cases are not clustered together, but are spread widely over a dozen or more exotic and native plants and some searching is required to find them.

Fig. 6. Cases littering the ground.

One question remains. Why do Saunders Case Moths sometimes form colonies? An individual case moth could possibly find safety in being part of a large group. But colonies of case moths are more vulnerable to predation from birds, wasps or accidents than are individuals. The two I have observed have both demonstrated boom and bust scenarios. I have no proven explanation, but can offer a hypothesis. Sometimes the newly hatched caterpillars do not disperse widely for two reasons. Firstly, a female ready to pupate may be unable find or climb to a high point to aid the dispersal of her hatchlings. Secondly, even if a female was at a high point when her eggs hatched, there may have been little or no breeze to spread the tiny caterpillars clinging to their silken threads. Thus, at times, many juveniles could end up congregated on a single shrub or tree close to where the female has produced her eggs.

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